

# Space Weather Prediction Testbed

**Rodney Viereck**

*Director, Space Weather Prediction Testbed*

*Space Weather Prediction Center*



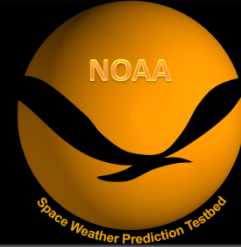
# Outline



- **Review of Customers**
- **Space Weather Prediction Testbed (SWPT)**
  - Objectives
  - Organization
- **Research-to-Operations activities (R2O)**
- **Operations-to-Research (O2R)**

# Space Weather Services:

## Critical to the World's Economy and Security



- **Electric Utilities**

- Potential for significant disruption of service due to geomagnetic storm with major \$ consequences
- FEMA addressing potential impacts related to space weather events through simulated exercise

- **Aviation**

- Polar route use – ~11,000 flights in 2011
- Next Generation Air Transportation System – GPS based

- **Communication**

- HF radio communication heavily relied upon by airlines, DOD, Emergency Managers, Search and Rescue, etc...

- **GPS**

- Single biggest source of error is ionosphere
- Strong growth in applications – surveying, drilling, precision agriculture, navigation, aviation

- **Space Systems**

- World satellite industry revenues in 2008: >\$144 billion
- Space weather support is critical for manned space flight and NASA robotic missions





# SWPT Objectives and Mission

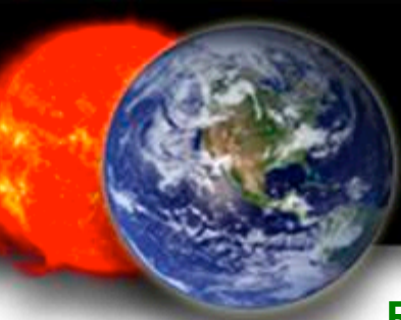


**Mission:** *To infuse new research and technology into operational space weather products and services thus improving the alerts, watches, warnings and forecasts of the Space Weather Prediction Center.*

## Objectives:

- **Identify** and investigate **new modeling capabilities**, research developments, and observational advances.
- **Test** and validate promising **numerical codes** and **forecast techniques** emerging from the research community
- **Conduct** and support focused **research** on forecast models and observational systems
- **Develop** usable customer-based **metrics** for model evaluation and forecast performance
- **Identify operational requirements** and **translate them into research requirements** for future scientific support



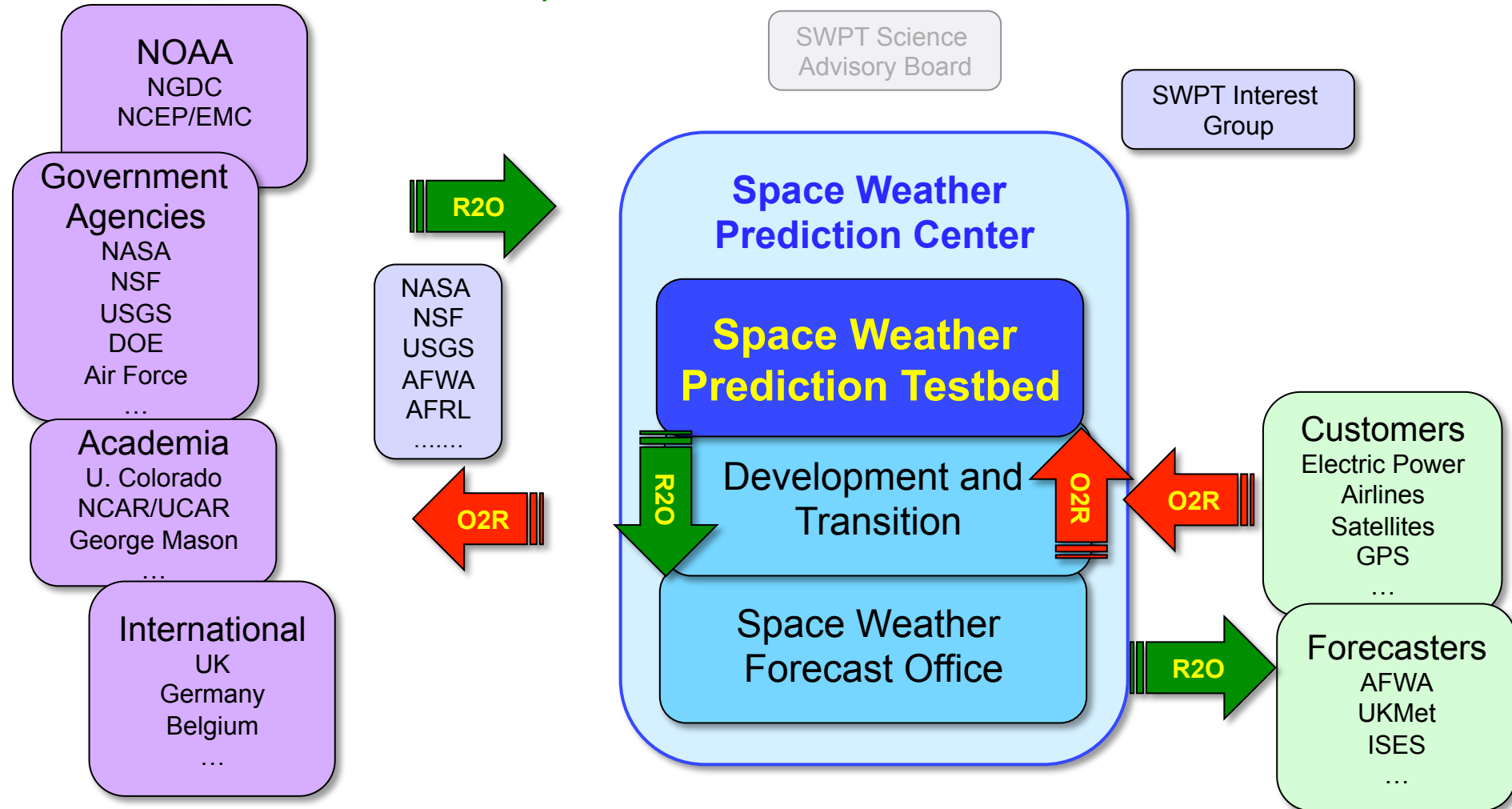


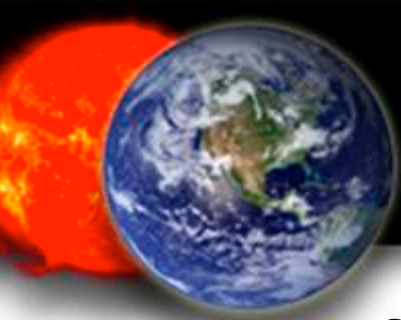
# Organization



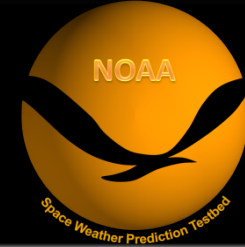
## Research Developments Research to Operations

## Requirements Operations to Research

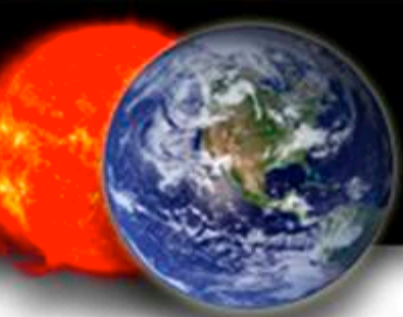




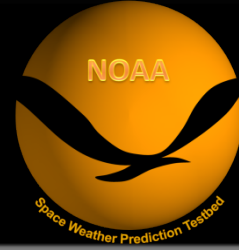
# SWPT Organization



- **Supervisory**
  - **SWPC Director:** Ultimate decision authority
  - **SWPT Director:** Responsibility to deliver
- **Staffing**
  - **6 Feds (Scientists)**
  - **21 CU/CIRES (Scientists, Postdocs, Students)**
- **SWPT Interest Group:**
  - **Communication with and recommendations from users, commercial service providers, academic community**
- **Scientific Advisory Board:**
  - **Oversight and advisory**
- **Concept of Operations currently under review**
- **Funding**
  - **NOAA SWPC Base Funds**
  - **NASA, NSF, DOD Grants**

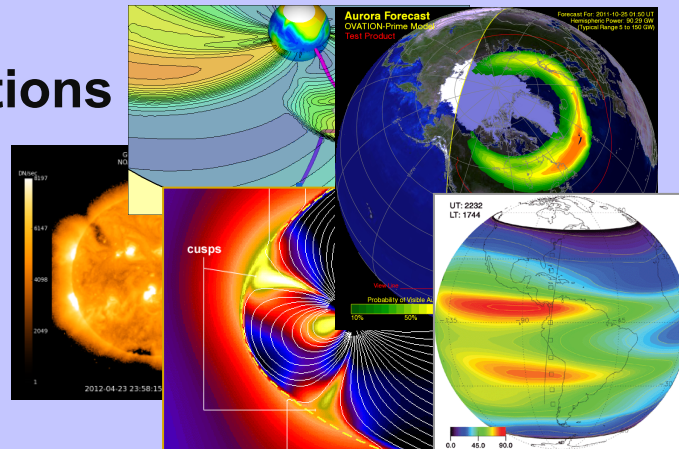


# SWPT Activities



## Research-to-Operations

- Research
- Applied Research
- Model Development
- Test/Evaluation
- Transition
- Operations Support



## Operations-to-Research

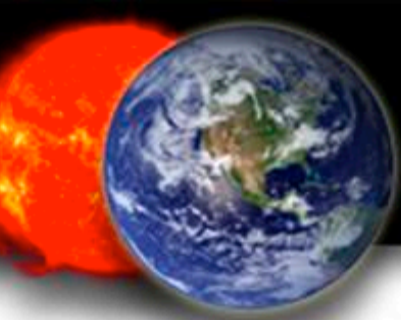
- Customer Requirements
- Observation Requirements
- Research Requirements

## Regions of Space



### Sun-to-Earth

1. Solar
2. Heliosphere
3. Magnetosphere
4. Ionosphere
5. Thermosphere
6. Atmosphere



# SWPT Activities



- Forecast solar flares: Using helioseismology to evaluate flare probabilities
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- International Collaboration: UKMet, EU, Korea, Taiwan,



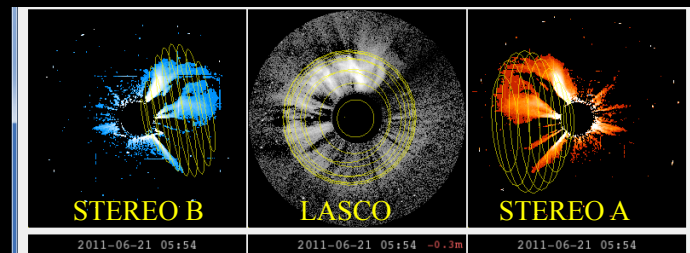
# WSA – Enlil

## Wang-Sheely-Arge-Enlil (WSA-Enlil) Model of the Solar Wind

3-View Tool for CMEs

**First Operational Physics-based space weather model running at NCEP**

**Greatly improved accuracy of geomagnetic storm forecasts.**



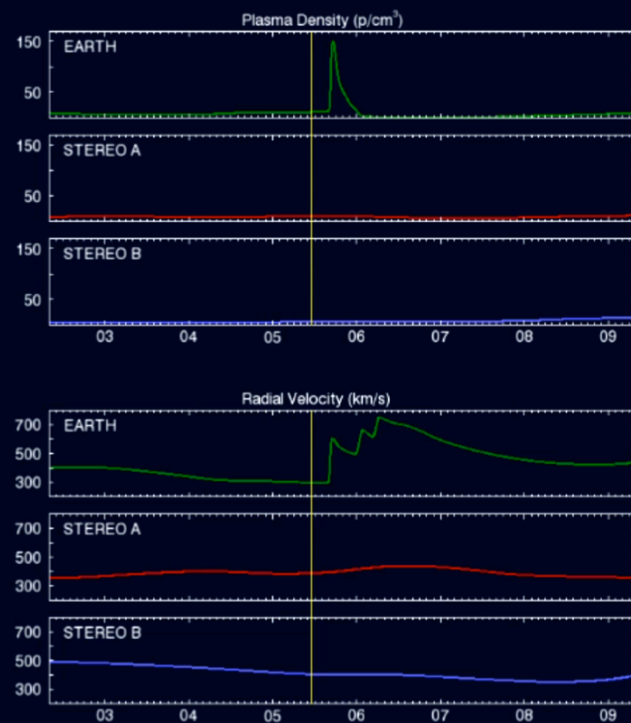
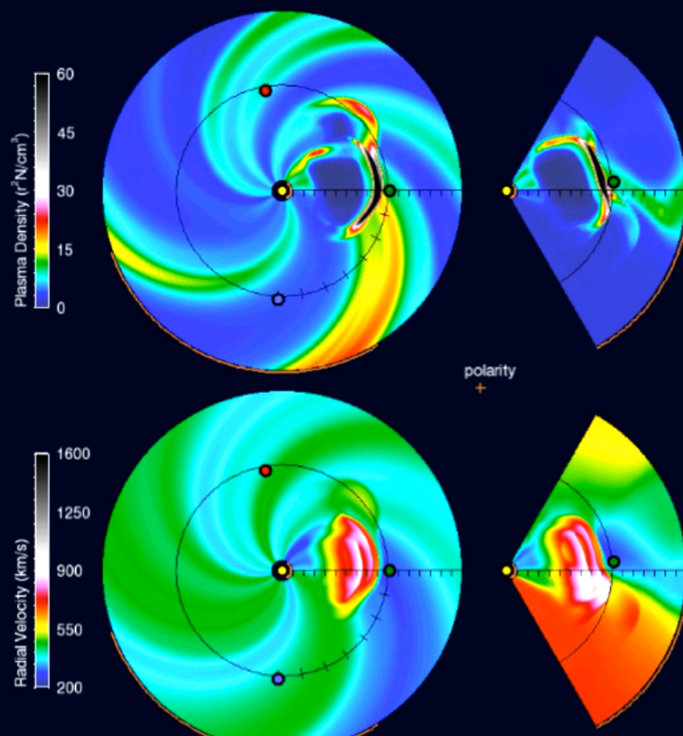
2011-08-05 10:00:00

### Storm Arrival Time

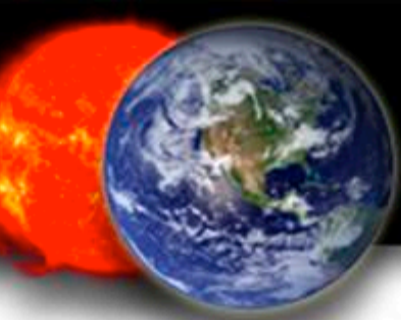
- Before +/- 18 Hours
- After +/- 6 Hours

**Inputs: Solar magnetograms, solar wind speed, and coronagraph data**

**Outputs: Solar wind speed and Earth**







# SWPT Activities

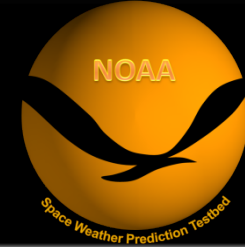


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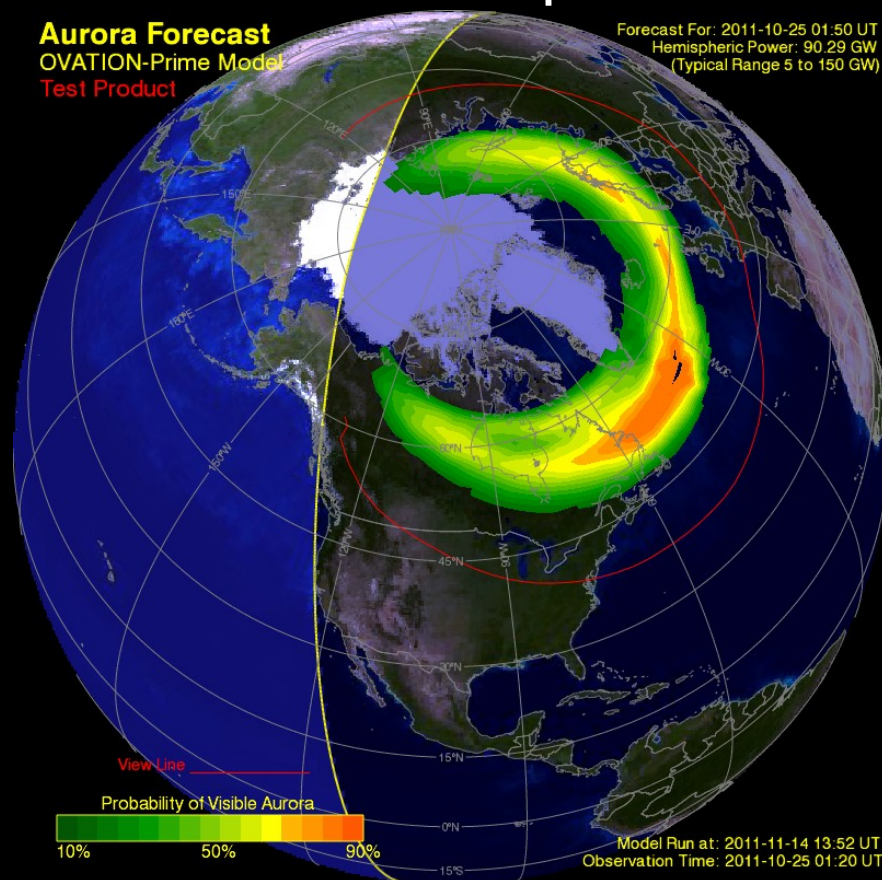


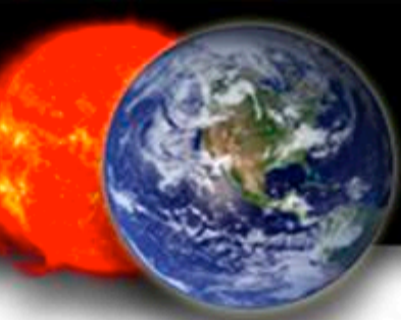


# R2O: Forecasting the Aurora



- Requirement: Specification and forecast of aurora (location, energy input to ionosphere, etc...)
- Solution: OVATION Prime, an empirical model of auroral particle precipitation based on correlations between solar wind conditions and observed particle precipitation.
- Task 1: Transition the current Ovation model from research to operations.
  - Validation of model performance
  - Developing outputs for customers
  - Develop AWIPS-2 Output
- Task 2: Improve the model
  - Expand to full range of geomagnetic storms
  - Develop fall back capability when ACE solar wind not valid (e.g. proton contamination)
  - Develop long-range forecast capabilities using WSA-Enlil

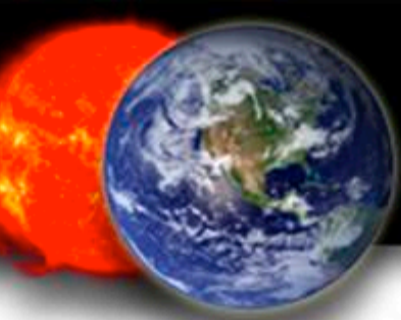




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# COSMIC 2: Ionospheric Data

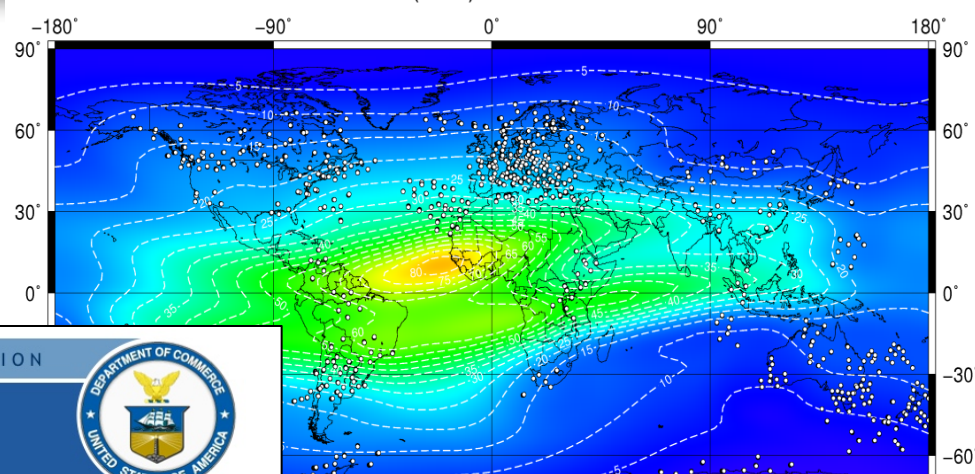


**Current products use ground-based GPS data**

- Gaps over oceans filled with climatologically models
- Satellites provide the best way to get global coverage
- Satellite Radio Occultation provides ionospheric profiles

Total Electron Content (TEC)

2012-05-02 16:55:00 UT



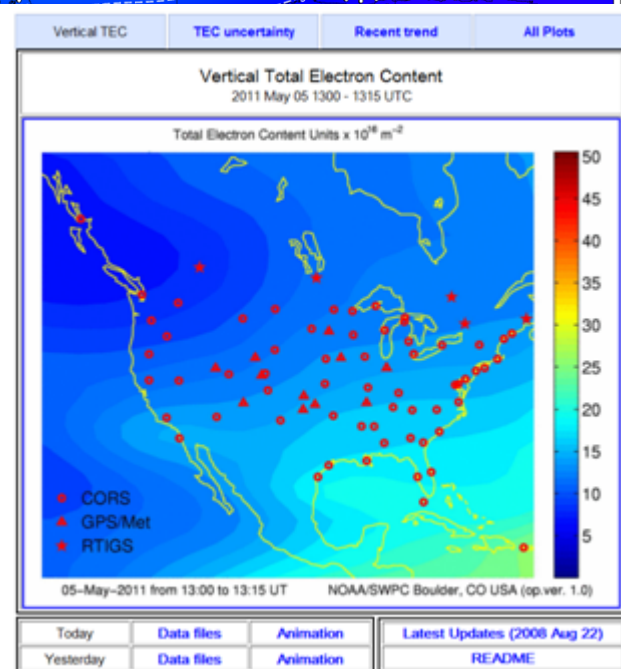
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

COSMIC-2 moving forward!



## COSMIC- 2 Operational Mission

- Supporting both space and terrestrial weather
- Taiwan building the spacecraft
- US Air Force Building the Sensors
- NOAA establishing downlink and processing
- 6 – Equatorial (Launch 2016)
- 6 – Polar (Launch 2018)
- 15,000 Ionospheric Soundings per Day
- Developing Data Assimilation Schemes



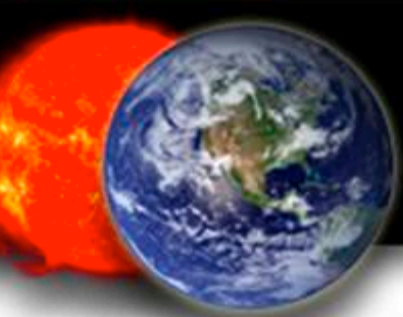


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# Whole Atmosphere Model

## Extending the Global Forecast Systems Model

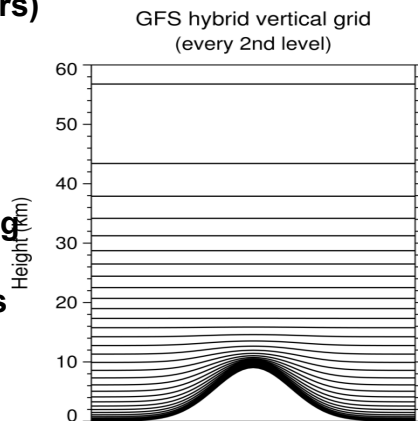
**WAM models the neutral atmosphere up to 600 km altitude to include the mesosphere and thermosphere**

### Global Forecast System (GFS) model

- Operational weather model
- T382L64 (~0-60 km Res.)
- 4 forecasts daily
- Global ensemble (14 members) forecasts up to 16 days

#### Physics

- O<sub>3</sub> chemistry & transport
- Radiative heating and cooling
- Cloud physics & hydrology
- Surface exchange processes
- Orographic gravity waves
- Eddy mixing and convection

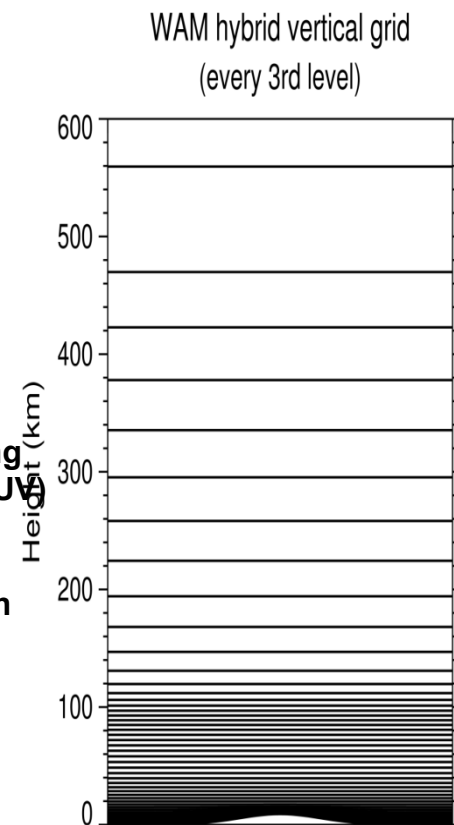


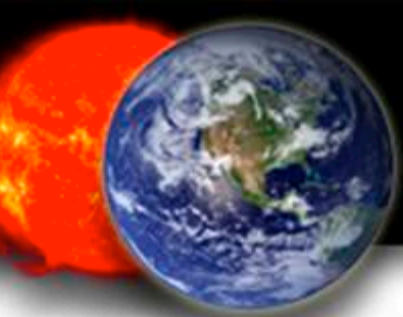
### Whole Atmosphere Model (WAM)

- T62L150 (0 – 600 km Res.)
- Variable Composition thermodynamics
- Timing ~ 1 Day requires 8 min/day on 32 nodes

#### Physics

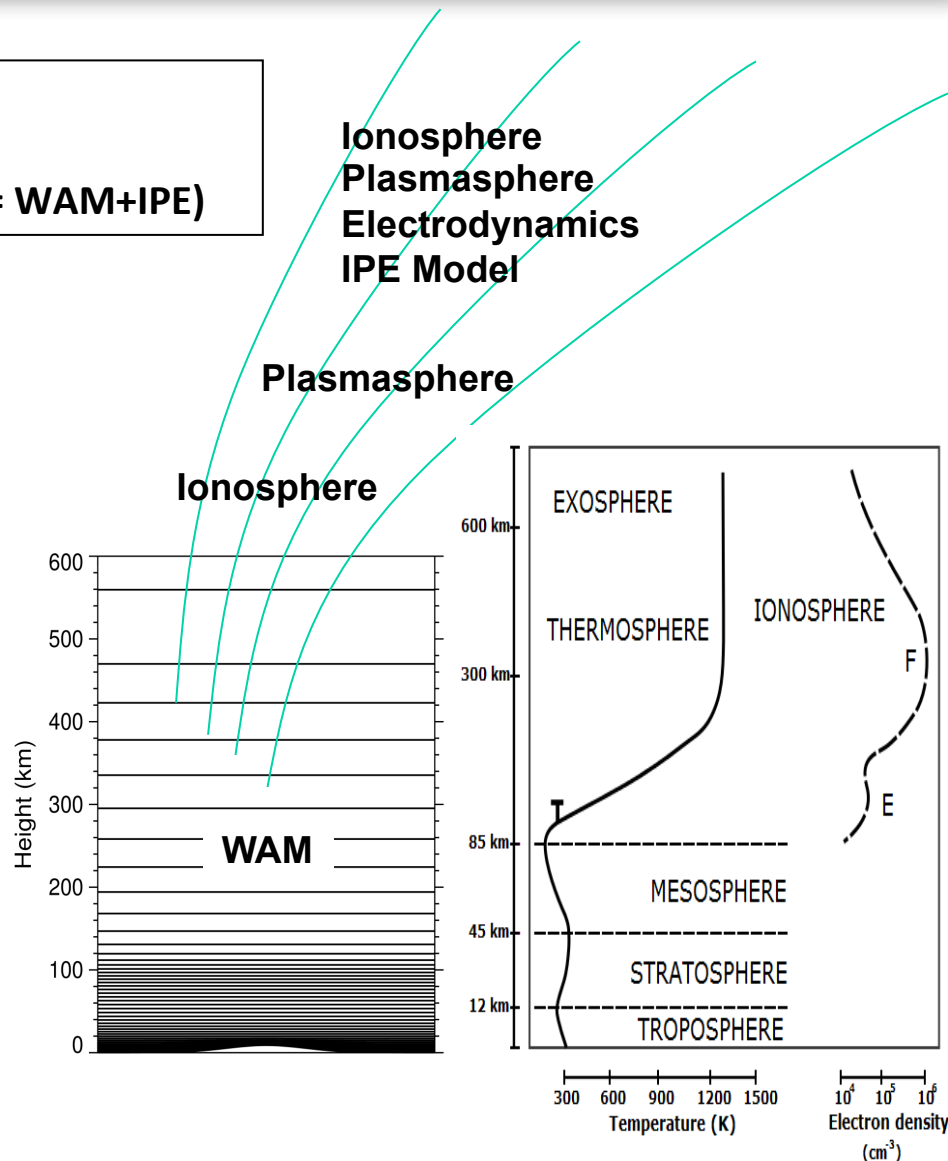
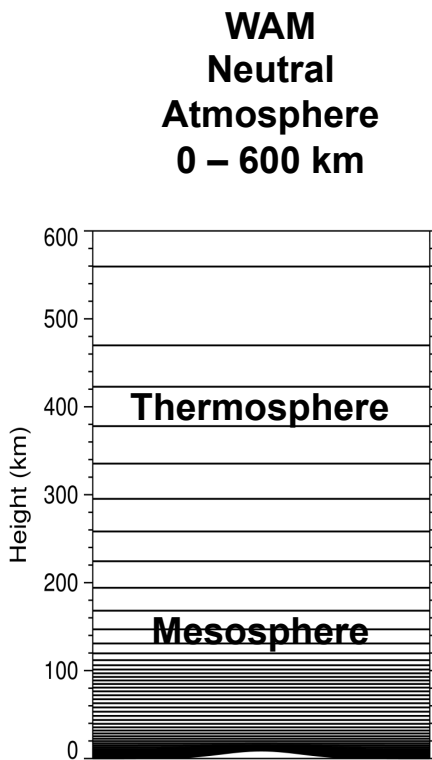
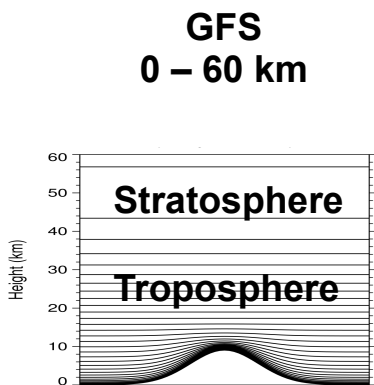
- Horizontal & vertical mixing
- Radiative heating (EUV & UV) and cooling (non-LTE)
- Ion drag & Joule heating
- Major species composition
- Non-orographic gravity waves
- Eddy mixing



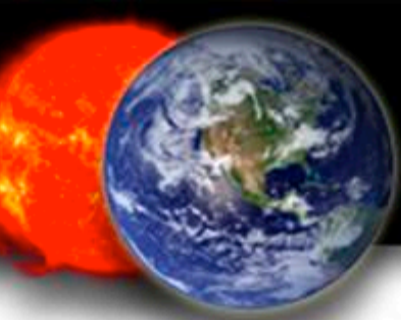


# R2O: Integrated Dynamics in Earth's Atmosphere

**Whole Atmosphere Model (WAM = Extended GFS)**  
**Ionosphere Plasmasphere Electrodynamics (IPE)**  
**Integrated Dynamics in Earth's Atmosphere (IDEA = WAM+IPE)**



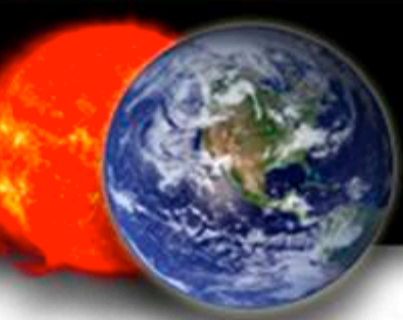




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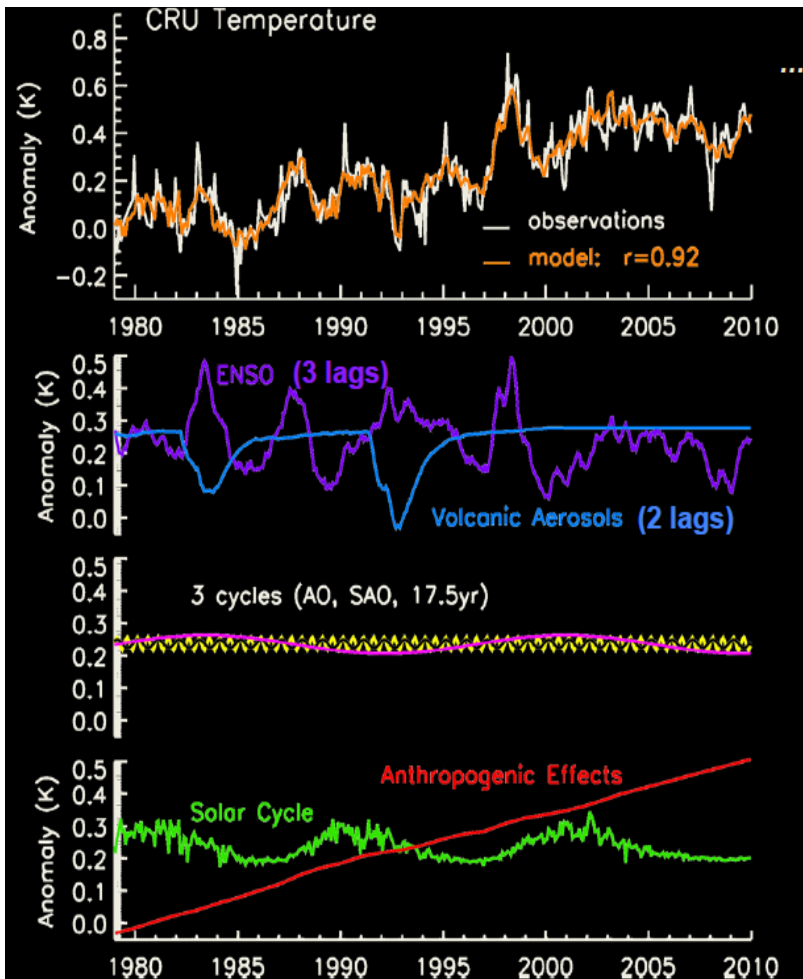


# Solar Forcing of Climate



## Solar contribution to climate change

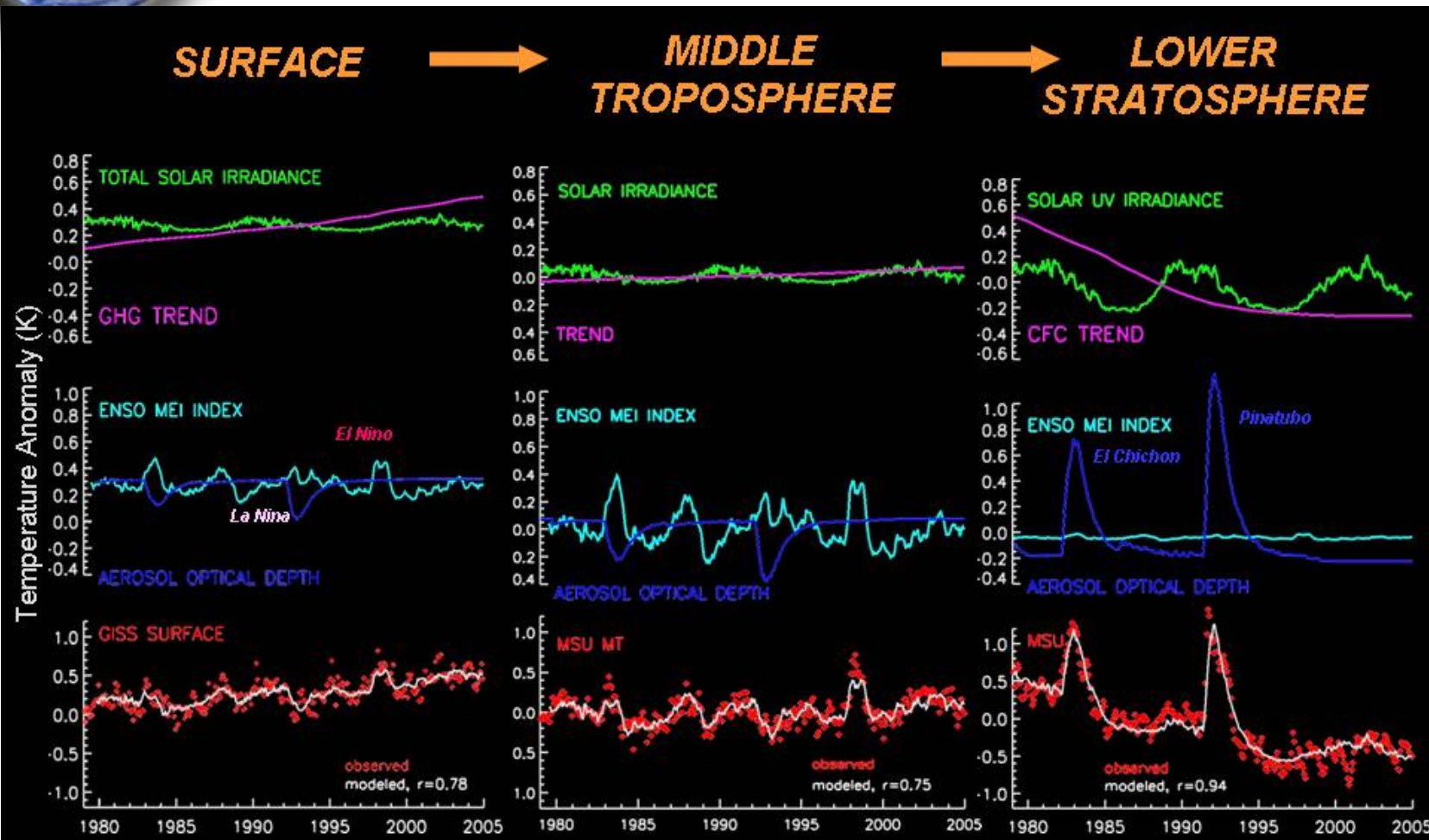
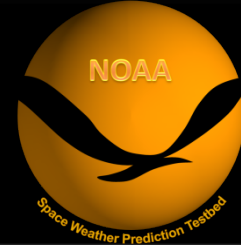
The last 30 years



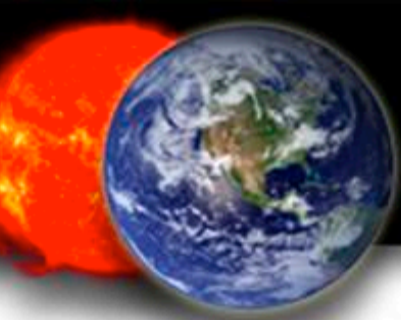
- **Empirical Model**
  - Fitting the climate forcing functions to the observations
  - Explains 75% of the variance
  - Magnitude of solar forcing is of similar magnitude to other forcing functions
  - Model works going back 130 years



# Solar Forcing of Climate Up Through the Atmosphere



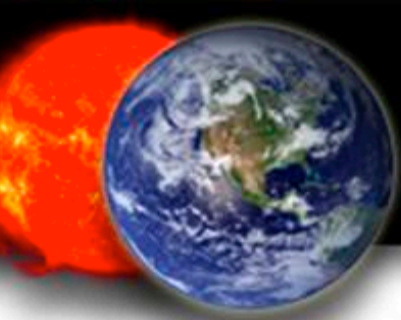
Approach: Michels & Knappenberger, 2000; Douglass & Clader, 2002; Van Loon and Shea, 2000; White et al., 1997 Data: Sato et al., 1993; Klaus Wolter, NOAA; Christy et al., 1998; GISS



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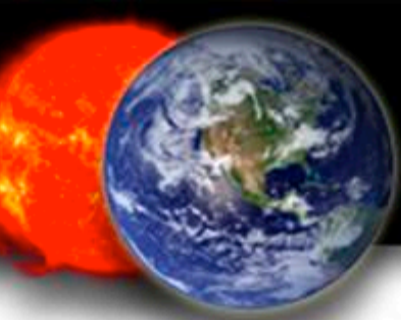


# O2R: Requirements for Space Weather Research

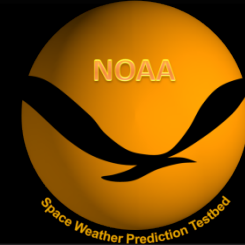


- **Forecasts of Solar Flares (timing and magnitude)**
  - Flares are the precursor to all major space weather storms
- **Forecasts of Solar Energetic Particle events and Radiation Storms**
  - Research required to insert energetic particles and electromagnetic shock physics into heliospheric models such as WSA-Enlil
- **Long lead-time warning of Coronal Mass Ejection arrival**
  - Improvement to initialization of background and CMEs in WSA-Enlil
  - Challenge: Forecast of Bz!
- **Spatially resolved forecasts of geomagnetic activity**
  - Requires magnetosphere model driven by solar wind.
- **Forecasts of the location and intensity of the Aurora**
  - Coupling WSA-Enlil output to the OVATION Prime model
  - Challenge: Forecasting Bz
- **Prediction of ionospheric scintillations and TEC gradients**
  - Coupled atmosphere-ionosphere models
  - Challenges:
    - Coupling with magnetospheric drivers
    - Forecasting solar energy inputs
    - Developing space weather data-assimilation schemes
- **Data Assimilation in all areas of space weather**
- **The development of ensemble forecast in space weather**





# Summary



## Space Weather Prediction Testbed

- Part of the Space Weather Prediction Center
- R2O: Bringing new research into the operational forecast center
- O2R; Bringing the needs of customers and forecaster to the research community

**Bridging the gap between research and operations**

